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Studies on Some Physical and Mechanical Properties of Moong Beans

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The present study was carried out to investigate the different physical and mechanical properties of three varieties of moong beans (SML 668, SML 832 and PAU 911) under different levels of moisture contents (3.24% to 28.25 %). The results showed that most of the physical properties such as size (length, width, thickness, arithmetic and geometric mean diameter) and shape (sphericity, surface area etc.) increased linearly with increase in moisture content for all the varieties although grains of variety SML 668 were bigger in size as compared to other varieties. Bulk density of moong bean grains decreased with increase in moisture content whereas true density and porosity showed a positive trend. Static coefficient of friction showed an upward trend with rise in moisture content for the three studied surfaces. As compared to other surfaces, the iron surface showed a lower coefficient at very low moisture content and a relatively higher coefficient at very high moisture content. For all the studied varieties, mean rupture force and rupture energy showed negative linear correlation with moisture content. Grains of PAU 911 variety had the highest rupture force and rupture energy i.e. 61.2 N and 8.30 N mm, respectively.

Key words: Moisture content, moong beans, physical properties, rupture force

Pulses are basically grain legumes. They occupy an important place in human nutrition due to their high protein content than cereal grains. Being the main source of protein it provides most of the essential amino acids to a certain degree. Moong beans (*Vigna radiata*) basically contain 23.86-27% protein, 1.15% fat, 3.32% ash, 62.62% carbohydrates, 16.3% fibre, 6.60% total sugars and 9.05% water (El-Adawy, 2000).

In India, about 80 per cent of the pulse production is consumed in the form of *dal* or powder and remaining 20 per cent as the whole seed and other forms. The removal of the outer layer of husk and splitting the grain into two equal halves is known as milling of pulses.Whole pulses are milled into split *dal* by various methods/processes. The recovery of *dal* varies from 60 per cent to 75 per cent, depending upon the type of pulses and techniques adopted by the millers such as methods of pre-treatment and milling machinery used. The storage of raw cleaned pulses is normally done at around 10 per cent moisture content. Generally, the husk is tightly attached to the cotyledons in pulses. In most pulses, husks are attached with cotyledons through a layer of gums. Hence, a pre-treatment in terms of addition of moisture given to pulse grain for loosening of the husk prior to milling is desirable as it increases the recovery of dal. During processing operation such as dehulling and splitting of moong beans, a lot of pretreatments in the form of addition of water and oil, drying etc. are given. With the addition/ removal of moisture, engineering properties are bound to change as proved by many researchers (Nimkar *et al.,* 2005, Chukwu and Sunmonu, 2010, Seifi and Alimardani, 2010 and Gharibzahedi *et al.,* 2011 for moth gram, cowpea, corn grains and castor seeds respectively).

The physical properties of moong beans, like those of other grains and seeds, are essential for the design of equipment and the analysis of the behaviour of the product during agricultural process operations such as handling, planting, harvesting, threshing, cleaning, sorting and processing. Principal axial dimensions of moong beans are useful in selecting sieve separators and in calculating grinding power during size reduction. These are important during modelling of grain drying, aeration, heating, and cooling. Bulk density, true density, and porosity (the ratio of inter granular space to the total space occupied by the grain) play an important role in many applications such as design of silos and storage bins, separation from undesirable materials, separation and grading, and maturity evaluation. The properties such as angle of repose, coefficient of external friction etc. help us to measure the flow ability of grains.

The objective of this study is to determine some selected engineering (physical and mechanical) properties of summer moong beans to establish a convenient reference data for mechanization and their processing.

Materials and Methods

The moong bean varieties; SML 668, SML 832 and PAU 911 obtained from the local farmers during 2011-12 were pre-cleaned to remove foreign

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matter, including dust and dirt, as well as broken and immature grains. The initial moisture content of the samples was determined using the hot air oven method (AOAC, 2000). The desired quantity of distilled water to be added, or moisture to be evaporated (seed to be dried) was calculated by using Eq 1 (Dursun and Dursun, 2005).

$$Q = \frac{W_i (M_f - M_i)}{(100 - M_f)} \quad (1)$$

where:

Q = mass of water to be added (kg)

Wi = initial mass of the sample (kg)

Mi = initial moisture content of the sample (%, w.b.)

Mf = final moisture content of the sample (%, w.b.)

The conditioned seeds were mixed thoroughly, packed in airtight containers and kept at 5±1°C in a refrigerator for a week to distribute moisture uniformly throughout the samples. The samples were brought to room temperature to determine the actual moisture content present in the sample prior to conducting the experiments for determination of its properties in triplicate. The average moisture content were 3.24%, 11.76%, 17.99%, 25.18% and 28.25% (w.b.) for SML 668 variety grains, 3.75%, 13.27%, 17.52%, 22.86% and 27.29% (w.b) for SML 832 variety grains and, 3.82%, 13.27%, 16.52%, 22.78% and 27.49% (w.b) for PAU 911 variety grains.

To determine the size and shape of the seeds, 1000 grains were randomly drawn from the bulk sample. For each individual seed, three principal dimensions, namely length (L), width (W) and thickness (T) were measured using digital calliper (with 0.001mm accuracy). These values were used to calculate arithmetic mean diameter (D_a) and geometric mean diameter (D_g), sphericity (Φ), surface area (S) and seed volume (V) of different varieties of moong beans by using standard relationships (Mohsenin, 1980).

The bulk density (ρ_b) of moong seed was determined by filling a 250 ml container with seeds from a height of 150 mm at a constant rate, tapping twice and then weighing the contents. The true density was determined by using the toluene displacement method. The porosity of the grains was calculated from the values of bulk and true densities using an established relationship (Mohsenin, 1980). The thousand grains mass was determined using a digital electronic balance of 1000 randomly selected grains and averaged. The estimation of bulk density, true density and thousand grains mass was carried out in triplicate and average values were reported.

The angle of repose (Φ) was calculated from the height and diameter of the naturally formed heap of the seeds on a circular plate (Kingsley *et al*., 2006). The static friction coefficient of the grains against three different surfaces, namely plywood, stainless steel sheet and galvanized iron sheet, were determined by using a laboratory set up in three replications.

Mechanical property such as rupture force and rupture energy absorbed were determined using TX-XT2i Texture Analyzer (Stable Microsystems) equipped with hardware (load cell with platform to hold sample and moving head for holding probe and software (Texture Expert) for recording and calculating the results of the tests. The test speed of 2mm s^{-1} was used with a distance of 3 mm with 75 mm compression platinum probe. The individual sample was loaded between the probe and the base plate and compressed at present conditions until rupture point (failure) occurred in the force deformation curve and the curve reached the peak force. The energy absorbed was calculated by determining the area under the force-deformation curve upto the seed rupture point (Kingsley *et al*., 2006).Regression analysis was carried out using Micro-soft Excel – 2007 software.

Results and Discussion

The geometric properties of moong beans, along with means and standard deviations, for three varieties are presented in Table 1. All geometric properties such as length, width, thickness, arithmetic mean diameter, geometric mean diameter, sphericity, surface area and unit volume, increased linearly with increasing moisture content with varying correlation coefficients. Size of the SML 668 variety grains was significantly higher than those of SML 832 and PAU 911 variety. So while doing grading, separate set of sieves may be required for variety SML 668 whereas same set of sieves may be used for SML 832 and PAU 911 grains. The average length, width, thickness, arithmetic mean diameter and geometric mean diameter increased linearly from 2.66 to 2.79 mm (R^2=0.9766), 1.25 to 1.39 mm (R^2=0.9169), 1.16 to 1.20 mm (R^2=0.9796), 1.69 to 1.79 mm (R^2=0.9545) and 1.57 to 1.67 mm (R^2=0.9485), respectively for SML 668, 1.84 to 2.02 mm (R^2=0.9251), 0.95 to 1.15 mm (R^2=0.9496), 0.95 to 1.02 mm (R^2=0.9268), 1.25 to 1.40 mm (R^2=0.9448) and 1.18 to 1.33 mm (R^2=0.9451), respectively for SML832 and 1.80 to 2.02 mm (R^2=0.94), 0.91 to 1.13 mm (R^2=0.9023), 0.94 to 1.01 mm (R^2=0.9781), 1.22 to 1.39 mm (R^2=0.9284) and 1.15 to 1.32 mm (R^2=0.9272), respectively for PAU 911, with increasing moisture content. The increase in the dimensions are attributed to expansion or swelling as a result of moisture uptake in the intracellular spaces within the seeds. Singh *et al.,* (2012) reported significant increase in length, width and thickness of flaxseed at moisture content of 3.95 to 17.21% d.b. The sphericity increased from 58.87 to 59.81% (R^2=0.7202) for SML 668, 64.26 to 65.98% (R^2=0.9276) for SML 832 and 64.07 to 65.37% (R^2=0.8467) for PAU 911as the moisture content increased linearly. Similar trend of increase in sphericity with increase in moisture content was observed by other authors for rapeseed and flaxseed (Izli *et al.,* 2009; Singh *et al.,* 2012). The surface area and unit volume of seeds increased linearly from 6.55 to 7.41 mm^2 (R^2=0.9533) and 2.07 to 2.50 mm^3 (R^2=0.9527), respectively for SML 668, 3.75 to 4.74

Table 1. Geometric properties of different varieties of summer moong beans at different moisture contents

Variety	Moisture content (% w.b.)	Length (mm)	Width (mm)	Thickness (mm)	Arithmatic mean diameter (mm)	Geometric mean diameter (mm)	Sphericity (%)	Surface area (mm^2)	Volume (mm^3)
SML 668	3.24	2.66 (0.23)	1.25 (0.16)	1.16 (0.13)	1.69 (0.17)	1.57 (0.17)	58.87 (1.33)	6.55 (1.41)	2.07 (0.67)
	11.76	2.70 (0.25)	1.28 (0.23)	1.17 (0.15)	1.72 (0.21)	1.59 (0.21)	58.83 (2.45)	6.78 (1.78)	2.20 (0.86)
	17.99	2.73 (0.24)	1.30 (0.21)	1.18 (0.14)	1.74 (0.21)	1.61 (0.20)	58.90 (2.08)	6.93 (1.67)	2.27 (0.82)
	25.18	2.75 (0.24)	1.34 (0.16)	1.19 (0.15)	1.76 (0.18)	1.64 (0.18)	59.43 (1.42)	7.13 (1.56)	2.36 (0.77)
	28.25	2.79 (0.26)	1.39 (0.14)	1.20 (0.13)	1.79 (0.18)	1.67 (0.17)	59.81 (0.46)	7.41 (1.48)	2.50 (0.74)
SML 832	3.75	1.84 (0.24)	0.95 (0.17)	0.95 (0.12)	1.25 (0.18)	1.18 (0.17)	64.26 (0.98)	3.75 (1.08)	0.91 (0.38)
	13.27	1.87 (0.26)	0.99 (0.22)	0.96 (0.15)	1.27 (0.21)	1.21 (0.21)	64.54 (2.23)	3.95 (1.34)	0.99 (0.49)
	17.52	1.93 (0.26)	1.04 (0.23)	0.99 (0.12)	1.32 (0.20)	1.26 (0.20)	64.95 (1.64)	4.24 (1.33)	1.09 (0.51)
	22.86	1.99 (0.25)	1.11 (0.16)	1.01 (0.14)	1.37 (0.18)	1.31 (0.18)	65.60 (0.70)	4.56 (1.23)	1.22 (0.48)
	27.29	2.02 (0.24)	1.15 (0.15)	1.02 (0.12)	1.40 (0.17)	1.33 (0.16)	65.98 (0.23)	4.74 (1.15)	1.28 (0.46)
PAU 911	3.82	1.80 (0.25)	0.91 (0.16)	0.94 (0.13)	1.22 (0.18)	1.15 (0.17)	64.07 (0.80)	3.57 (1.06)	0.84 (0.37)
	13.27	1.83 (0.24)	0.93 (0.23)	0.96 (0.14)	1.24 (0.20)	1.18 (0.21)	64.05 (2.90)	3.73 (1.28)	0.91 (0.45)
	16.52	1.92 (0.24)	1.03 (0.23)	0.97 (0.12)	1.31 (0.20)	1.24 (0.20)	64.49 (2.16)	4.14 (1.29)	1.06 (0.48)
	22.78	1.98 (0.25)	1.09 (0.17)	0.99 (0.14)	1.35 (0.19)	1.29 (0.18)	64.96 (0.99)	4.43 (1.24)	1.17 (0.48)
	27.49	2.02 (0.26)	1.13 (0.16)	1.01 (0.13)	1.39 (0.18)	1.32 (0.18)	65.37 (0.29)	4.66 (1.23)	1.25 (0.49)

Figures in parenthesis are standard deviations

mm^2 (R^2=0.9530) and 0.91 to 1.28 mm^3 (R^2=0.9588), respectively for SML 832 and 3.57 to 4.66 mm^2 (R^2=0.9345) and 0.84 to 1.25 mm^3 (R^2 =0.9389), respectively for PAU 911. Similar trends of results have been reported for millet (Baryeh, 2002) and for faba beans (Altuntas and Yıldız, 2007).

The 1000 grain weight increased linearly with increase in moisture content (Fig 1). Mass of SML 668 seeds increased from 47.4 g at 3.24% w.b. to 65.6 g at 28.25 % w.b., mass of SML 832 seeds increased from 36.6 g at 3.75 % w.b. to 48.4 g at 27.29% w.b. and that of PAU 911 seeds increased from 35.0 g at 3.82% w.b. to 44.4 g at 27.49% w.b. (Table 2). This parameter is useful in determining the equivalent diameter which can be used in the theoretical estimation of seed volume and in cleaning using aerodynamic forces as studied in linseed, flaxseed, sunflower seed (Selvi *et al.,* 2006; Coskuner and Karababa, 2007; Isik and Izli, 2007).

The bulk density of moong seeds decreased as the moisture content increased (Fig 2). In SML 668 variety, it decreased from 829 kg/m^3 at 3.24% w.b. to 736.66 kg/m^3 at 28.25% w.b., and it decreased from 862.7 kg/m^3 at 3.75% w.b. to 777.4 kg/m^3 at 27.29% w.b. (SML 832) while for PAU 911 variety, it decreased from 856.6 kg/m^3 at 3.82% w.b. to 782.1 kg/m^3 at

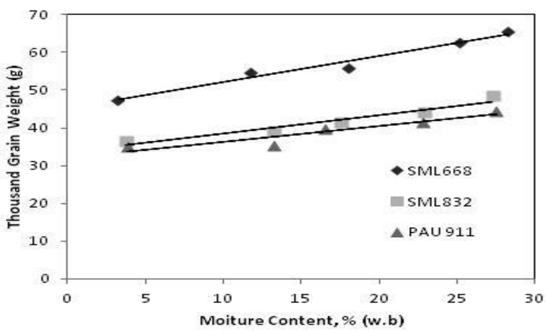

Fig 1. Effect of moisture content on thousand grain weight of three moong bean varieties.

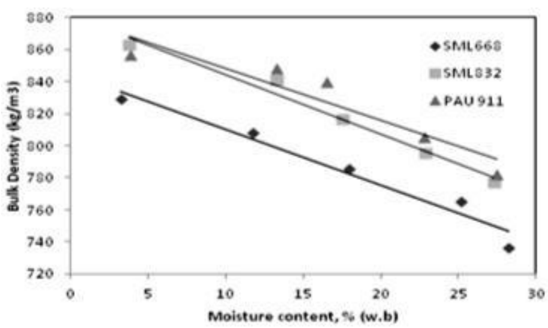

Fig 2. Effect of moisture content on bulk density of seeds of three moong bean varieties.

27.49% w.b. with varying correlation coefficients (Table 2). The decrease in bulk density with increase in moisture content shows that the increase in mass resulting from the moisture gain of the sample is lower than the accompanying volumetric expansion of the bulk. The negative linear relationship of bulk density

Table 2. Relationship between moisture content (*M*) and thousand grain mass, bulk density and true density of moong beans

Variety	Thousand grain mass		Bulk density		True density	
	Equation	R^2	Equation	R^2	Equation	R^2
SML 668	0.6932M + 45.29	0.973	-3.4831M + 845.09	0.960	0.5756M + 1177.3	0.951
SML 832	0.4865M + 33.759	0.941	-3.722M + 881.7	0.976	0.2924M + 1243.4	0.966
PAU 911	0.4161M +32.219	0.881	-3.2342M + 880.76	0.873	0.4504M + 1241	0.971

with moisture content was also observed by various research workers (Bart- Plange and Baryeh, 2003; Gharibzahedi *et al.,* 2010). The developed

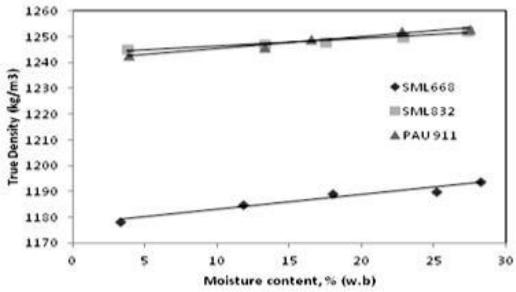

Fig 3. Effect of moisture content on true density of seeds of three moong bean varieties.

mathematical relationships between bulk density (ρ_b) and moisture content (M) are presented in Table 2. Some authors (Bamgboye and Adebayo, 2012) have

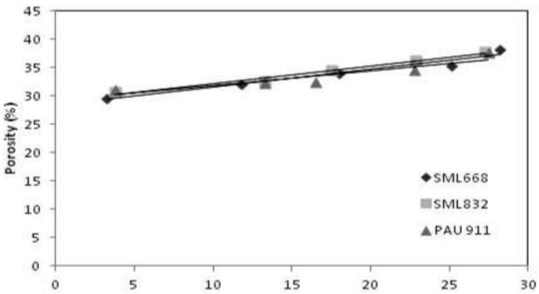

Fig 4. Effect of moisture content on porosity in the seeds of three moong bean varieties.

predicted the increase in the bulk density with increase in moisture content from 5.85–25.85% for *Jatropha curcas*. The discrepancies could be due to

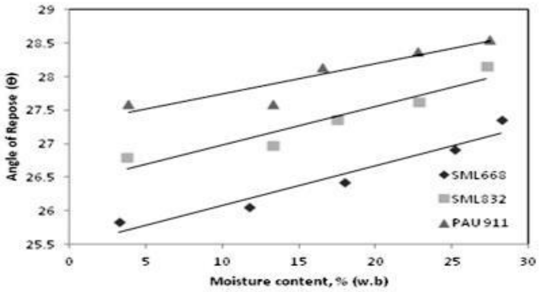

Fig 5. Effect of moisture content on angle of repose of seeds of three moong bean varieties.

the cell structure and the volume and mass increased characteristics of the grains, seeds and nuts and their kernels as moisture content increased.

The effect of moisture content on the true density of the grains showed an increasing trend with increasing moisture content (Fig 3). The true density for SML 668 increased from 1178.2 kg/m^3 at 3.24% w.b. to 1194 kg/m^3 at 28.25% w.b., for SML 832, it increased from 1245 kg/m^3 at 3.75% w.b. to 1252 kg/ m^3 at 27.29% w.b. and for PAU 911, it increased from 1243 kg/m^3 at 3.82% w.b. to 1253 kg/m^3 at 27.49% w.b. The increasing trend was expected since both

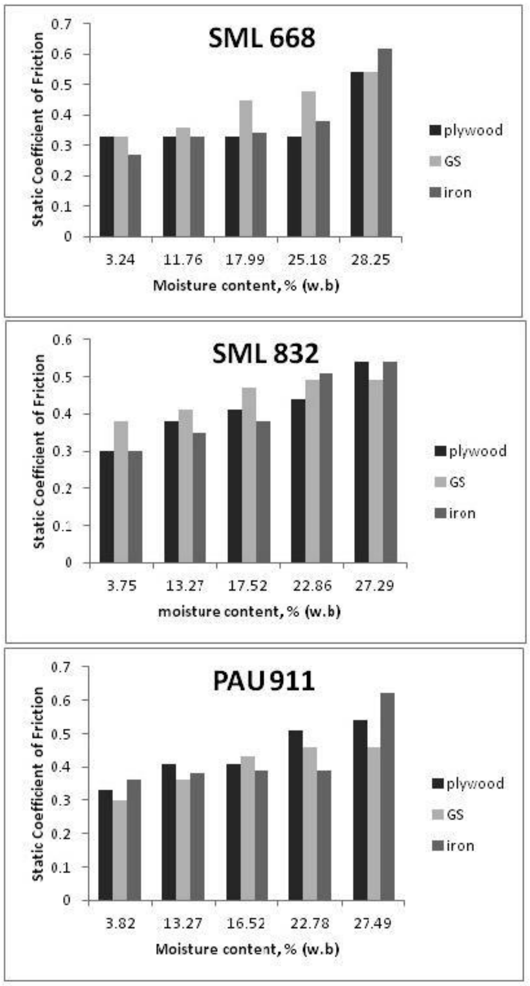

Fig 6. Effect of moisture content on static coefficient of friction in seeds of three moong bean varieties.

the mass and volume on which particle density is based increased with increasing moisture content. The moisture (M) dependence of the true density (ρ_t) for SML 668, SML 832 and PAU 911 has been described by linear equations (Table 2).

Although the results were similar to those reported for faba bean grains and jatropha seed (Altuntaş and Yildiz, 2007; Garnayak *et al*., 2008), a reverse trend was also reported for pea seed, barbunia bean seed and legumes seeds (Yalcin *et al*., 2007; Cetin, 2007; Altuntaş and Demirtola, 2007).

Table 4. ANOVA to study the effect of variety and moisture content of moong bean on mean rupture force and rupture energy

Parameter	Source	Sum of squares	Degree of freedom	Mean square	$F_{calculated}$
Mean rupture force, N	Moisture	589.7353	2	294.8676	252.9716[a]
	Variety	1359.945	4	339.9864	291.6797[a]
	Moisture *variety	47.96033	8	5.995041	5.14324[a]
	Error	34.96847	30	1.165616	
Rupture energy, N-mm	Moisture	20.04739	2	10.0237	1269.894[a]
	Variety	6.463524	4	1.615881	204.7147[a]
	Moisture *variety	0.906476	8	0.113309	14.35508[a]
	Error	0.2368	30	0.007893	

Moisture*variety: interaction of moisture and variety, [a]significant at p≤0.05

The porosity of moong grains increased with the increase in moisture content (Fig 4). It increased from 29.64% at 3.24% w.b. to 38.3% at 28.25% w.b. (SML 668), for SML 832, it increased from 30.71% at 3.75% w.b. to 37.9% at 27.29% w.b. and for PAU 911, it increased from 31.09% at 3.82% w.b. to 37.58% at 27.49% w.b. This could be attributed to the expansion and swelling of seeds that might have resulted in more voids space between the seeds and increased the bulk volume. This is also exhibited in the reduction of bulk density with increase in moisture content. Bamgboye and Adebayo (2009) have reported similar results.

Table 3. Effect of moisture content on compression loading behaviour of moong beans

Variety	Moisture content (% w.b.)	Mean Rupture force (N)	De formation (mm)	Rupture Energy absorbed (N-mm)
SML668	3.24	56.10 (3.11)	0.54(0.04)	8.10 (1.11)
	11.76	49.69 (3.12)	0.539(0.05)	7.42 (1.52)
	17.99	43.11 (2.91)	0.511 (0.02)	7.02 (1.55)
	25.18	40.10 (2.51)	0.505(0.06)	6.94 (1.61)
	28.25	39.80 (2.71)	0.501(0.03)	6.71 (1.12)
SML832	3.75	59.10 (2.11)	0.470(0.04)	7.21 (1.81)
	13.27	51.44 (2.23)	0.429(0.03)	6.47 (1.67)
	17.52	49.12 (1.92)	0.419(0.01)	6.22 (1.99)
	22.86	45.11 (3.10)	0.401(0.05)	6.01 (2.01)
	27.29	42.56 (2.65)	0.396(0.01)	5.92 (2.12)
PAU911	3.82	61.20 (2.53)	0.502(0.03)	8.30 (1.14)
	13.27	57.48 (2.01)	0.499(0.04)	8.10 (1.16)
	16.52	54.21 (2.29)	0.487(0.00)	7.94 (1.00)
	22.78	50.12 (2.28)	0.481(0.02)	7.91 (1.21)
	27.49	48.13 (2.22)	0.471(0.01)	7.71 (0.91)

Figures in parenthesis are standard deviations

The values of angle of repose were found to increase with increase in the moisture content (Fig 5). For SML 668, it increased from 25.83º at 3.24% w.b. to 27.35º at 28.25% w.b. (R^2 = 0.9374), for SML 832, it increased from 26.79º at 3.75% w.b. to 28.16º at 27.29% w.b. (R^2 = 0.9019) and for PAU 911, it increased from 27.59º at 3.82% w.b. to 28.56º at 27.49% w.b. (R^2 = 0.8487). This increasing trend of repose angle with moisture content occurs because surface layer of moisture surrounding the particle holds the aggregate of grain together by the surface tension. The angle of repose is also important in designing the equipment for mass flow and structures for storage. These results are similar to those reported by Kasap and Altuntaş (2006), Altuntaş and Yildiz (2007) and Garnayak *et al.* (2008) for sugar beet seeds, faba bean grains and jatropha seed, respectively.

The static friction coefficients of the grains on three surfaces of plywood, galvanized steel sheet and iron sheet against moisture content for three varieties of moong beans revealed that it increased linearly with moisture content for all contact surfaces (Fig 6). The reason for the increased friction coefficient at higher moisture content may be owing to the water present in the grain, which offers a cohesive force on the surface of contact. The friction coefficient is important in the design of conveyors because friction is necessary to hold the grains to the conveying surface without slipping or sliding backward. On the other hand, discharging requires less friction to enhance the discharging process.

The increase in moisture content of seeds caused the decrease in rupture force irrespective of variety (Table 3). The decrease in rupture force ranged from 56.1 N at 3.24 % w.b. to 39.8 N at 28.25% w.b. for SML 668, from 59.1 N at 3.75% w.b. to 42.56 N at 27.29% w.b. for SML 832 and from 61.2 N at 3.82% w.b. to 48.13 N at 27.49% w.b. for PAU 911. Similar findings were reported for dried pomegranate seeds (Kingsley *et al.*, 2006). The trends in deformation and rupture energy with respect to moisture content were similar to that of mean rupture force. Moisture content and variety as well as their interaction had a significant effect on load behaviour parameters at 5% level of significance (Table 4).

Most of the physical properties such as size (length, width, thickness, arithmetic and geometric mean diameter) and shape (sphericity, surface area etc.) increased linearly with moisture content for all the varieties although grains of variety SML 668 were bigger in size as compared to other varieties

Bulk density of moong bean grains decreased with increase in moisture content whereas true density and porosity showed a positive trend.

Static coefficient of friction showed an upward trend with rise in moisture content for the three studied surfaces. As compared to other surfaces, the iron surface showed a lower coefficient at very low moisture content and a relatively higher coefficient at very high moisture content.

Among the varieties, PAU 911 had the highest rupture force and rupture energy i.e. 61.2 N and 8.30 N mm respectively.

Moisture content and variety as well as their interaction had a significant effect on load behaviour parameters of moong beans at 5% level of significance.

References

Altuntas, E. and Demirtola, H. 2007. Effect of moisture content on physical properties of some grain legume seeds, *N.Z.J. Crop Horti Sci.,* **35:** 423-433.

Altuntas, E. and Yildiz, M. 2007. Effect of moisture content on some physical and mechanical properties of faba bean (*Vicia faba* L.) grains, *J. Food Eng.,* **78**: 174-183.

AOAC, 2000. Official Methods of Analysis. Washington,DC, USA.

Bamgboye, A.I. and Adejumo, I.O. 2009. Physical Properties of Roselle (*Hibiscus sabdariffa* L.) Seed, Agri. Eng. Int.: the CIGR Ejournal. Manuscript 1154. Vol. XI. March.

Bamgboye, A.I. and Adebayo, S.E. 2012. Seed moisture dependent on physical and mechanical properties of *Jatropha curcas, J. Agri. Technol*., **8:** 13-26.

Bart-Plange, A. and Baryeh, E.A. 2003. The physical properties of category B cocoa beans, *J. Food Eng.,* **60**: 219–227.

Baryeh, E.A. 2002. Physical properties of millet, *J. Food Eng.,* **51**: 39–46.

Cetin, M. 2007. Physical properties of barbunia bean (*Phaseolus vulgaris* L. cv. ‘Barbuniz’) seed, *J. Food Eng.,* **80**: 353-358.

Chukwu, O. and Sunmonu, M.O. 2010. Determination of selected engineering properties of cowpea (*Vigna unguiculata*) related to design of processing machines, *Pak J. Agri. Eng. Vet. Sci., **26***: 70-79.

Coskuner, Y. and Karababa, E. 2007. Some physical properties of flaxseed (*Linum usitatissimum* L.), *J. Food Eng.,* **78**: 1067–1073.

Dursun, E. and Dursun, I. 2005. Some physical properties of caper seed, *Biosyst. Eng.,* **92**: 237-245.

El-Adawy, T.A. 2000. Functional properties and nutritional quality of acetylated and succinylated mung bean protein isolate, *Food Chem.,* **70**: 83-91.

Garnayak, D.K., Pradhan, R.C., Naik, S.N. and Bhatnagar, N. 2008. Moisture-dependent physical properties of Jatropha seed (*Jatropha curcas* L.), *Indian Crop Product*, **27**: 123-129.

Gharibzahedi, S.M.T., Etemad, V., Mirarab -Razi, J. and Fos’hat, M. 2010. Study on some engineering attributes of pine nut (*Pinus pinea*) to the design of processing equipment, *Res. Agri Eng*., **56**: 99–106.

Gharibzahedi, S.M.T., Mousavi, S.M. and Ghahderijani, M. 2011. A survey on moisture-dependent physical properties of castor seed (*Ricinus communis* L.), *Australian J. Crop Sci.,* **5**: 1-7.

Isik, E. and Izli, N. 2007. Physical properties of sunflower seeds, *Int. J. Agri. Res.,* **2**: 677-686.

Izli, N., Unal, H. and Sincik, M. 2009. Physical and mechanical properties of rapeseed at different moisture content, *Int. Agrophysics*, **23**: 137-145.

Kasap, A. and Altuntaş, E. 2006. Physical properties of monogerm sugarbeet (*Beta vulgaris* var. *altissima*) seeds, *N. Z. J. Crop Horti. Sci.,* **34**: 311-318.

Kingsley, A.R.P., Singh, D.B., Manikantan, M.R. and Jain, R.K. 2006. Moisture dependent physical properties of dried pomegranate seeds, *J. Food Eng.,* **75**: 492-496.

Mohsenin, N.N. 1980. Physical Properties of Plant and Animal Materials, Gordon and Breach Press, New York, USA.

Nimkar, P.M., Mandwe, D.S. and Dudhe, R.M. 2005. Physical Properties of Moth Gram, *Biosyst. Eng.,* **91**: 183–189.

Seifi, M.R. and Alimardani, R. 2010. Comparison of moisture-dependent physical and mechanical properties of two varieties of corn (Sc 704 and Dc 370), *Australian J. Agri. Eng.,* **1**: 170-178.

Selvi, K.C., Pinar, Y. and Yesiloglu, E. 2006. Some physical properties of linseed, *Biosyst. Eng.,* **95**: 607-612.

Singh, K.K., Mridula, D., Barnwal, P. and Rehal, J. 2012. Physical and chemical properties of flaxseed, *Int. Agrophysics,* **26**: 423-426.

Yalcın, I., Ozarslan, C. and Akbaş, T. 2007. Physical properties of pea (*Pisum sativum*) seed, *J. Food Eng.,* **79**: 731-735.

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